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ABSTRACT

The primary purpose of the reported study was to identify a possible interaction between the cognitive style of the students and the instructional sequence of the materials and their combined effect on achievement. The subjects were 627 biology students from six midwestern high schools. The students were ranked and classified as field-dependent (FD) or field-independent (FI) students, and were randomly assigned to one of three levels of instructional materials: (1) a deductively sequenced package (DED); (2) an inductively sequenced package (IND) of instruction; and (3) a control group pursuing three related units of high school biology. A pretest-posttest control design was used. The study recommends individualizing instruction in such a way that global FD students are matched with deductive materials and analytic FI students are matched with inductive materials. (Author/GA)

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THE EFFECT OF FIELD-DEPENDENCE-INDEPENDENCE AND INSTRUCTIONAL SEQUENCE ON THE ACHIEVEMENT OF HIGH SCHOOL BIOLOGY STUDENTS

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Introduction

The primary purpose of this research was to identify a possible interaction between the cognitive style of the students and the instructional sequence of the materials and their combined effect on achievement. It was hypothesized that the field-dependent (FD) student would reach a higher level of achievement with a deductive (DED) sequence of instruction than would be expected with an inductive (IND) sequence of instruction, and that the field-independent (FI) learner would experience greater success using an IND set of materials than would be expected if DED materials were used for instruction.

Field-dependence-independence describes a generalized approach to one's interaction with the environment, including the analysis of problem solving tasks. A FI, or analytic, person is able to analyze a stimulus distinguishing, retaining, and coordinating relevant items extracted from a distracting background. On the other hand, the FD person is unable to structure a stimulus and to perceive its parts as discrete from the overall field of reference. This global quality is indicative of a limited ability to discriminate between the object of primary importance and the surrounding distractions. In general, FI subjects are less prone to be influenced by irrelevant perceptual "noise" when they attend to a problem than are FD subjects (Witkin et al., 1967).

Many science topics may be taught by either an IND or a DED sequence of instruction. An IND approach proceeds from particular facts or individual cases to a general conclusion, while a DED approach begins with a general overview and proceeds to cite individual examples. Often, induction is referred to the didactic or expository approach. Ausubel (1964) defended verbal learning as an appropriate means of instruction for some students and said that school experiences needed to be set within a context familiar to the student. Walters and Sieben (1974) supported this point of view recommending that for students who did not learn well in an unstructured environment, the teacher might need

to provide more specific directions and to offer direct assistance in the development of logical relationships. Thus, it might be proposed that FD students might need their learning experiences clearly defined within their field of reference. Intellectual problems, especially those calling for creative activity, often require that specific parts or elements be separated from the context in which they are embedded and brought into new relationships (Wertheimer, 1945). Several investigators have shown that FI is correlated strongly with one's ability to sift through a series of possible solutions and select the one best solution to a problem (Ehri & Mirzio, 1974; Long, 1962). The literature strongly supports the contention that the FI student is more likely to achieve success with IND materials than is the FD student (Saarni, 1973).

This research stemmed from the recommendations of several investigators who emphasized the importance of cognitive style and instructional sequence (Coop & Sigel, 1971; Rowe & DeTure, 1975; Walters & Sieben, 1974) and from an earlier study done by the authors (Douglass & Kahle, 1977) which recommended the use of a large and diverse sample.

Methods

The subjects for this study were 627 (312 female and 315 male) biology students from six midwestern high schools. The schools were chosen carefully in order to maximize the range of student ability, student motivation, parent affluence, and school location (rural, suburban, and urban).

The two levels of instructional sequence, IND and DED, and the two levels of cognitive style, FI and FD, were factorially combined to form a 2 by 2 pretest-posttest control group design (Campbell & Stanley, 1963).

The students were ranked and classified as FD or FI on the basis of their performance on the Group Embedded Figures Test (GEFT) (KR_{21} = 0.88). The GEFT was chosen as a valid assessment of field-dependence-independence based upon

high correlations with the portable Rod-and-Frame test and the individual EFT (Witkin et al., 1971). The students were then assigned randomly to one of the following three groups: 1) an experimental group pursuing a DED package of instruction, 2) an experimental group pursuing an IND package of instruction, or 3) a control group. The Otis-Lennon Mental Ability Test (KR_{21} = 0.92) was administered as a measure of general intelligence. All students were pretested over the treatment material. A comprehensive posttest measured student achievement.

The treatment and control groups were equivalent on the basis of derived IQ ($F(2,558) = 0.21$, $p < .05$), cognitive style ($F(2,574) = 0.18$, $p < .05$), and pretest score ($F(2,589) = 0.36$, $p < .05$).

Materials

The instructional materials were developed in an audiotutorial, self-paced, mastery format. The subject matter content for the treatment units included topics in Mendelian genetics and probability. The control units were identical to the treatment units except in content as their purpose was to control for the learning of content material by some means other than the treatment such as television or instruction in another class.

The evaluation materials included two equivalent forms of formative tests which were available at the end of each unit. If the student did not reach 70% mastery on the first test, he reviewed the materials and was retested. In addition, two equivalent forms of a 31-item, summative test were developed which were used as a pretest (KR_{21} = 0.75) and as a posttest (KR_{21} = 0.93). The control group took the same summative tests to identify the effects of attrition and random events occurring between the time of the pretest and the posttest.

Three external judges validated all instructional and evaluative materials. In all cases, the instructional sequence, objectives and test items were

judged unambiguous and relavent to the high school biology student in both content and presentation.

Results

The independent variables for this study were cognitive style and the sequence of the instructional materials. The dependent variables were posttest score and gain score (posttest minus pretest). Derived IQ was used as the covariate in the ANCOVA. Since the correlation between derived IQ and the degree of FI was $r = 0.61$ ($N = 604$, $p < .001$), ANCOVA was chosen rather than ANOVA (Cochran, 1957).

The mean pretest, posttest, and gain scores were calculated for both treatment groups and the control group. The gain scores are as follows: deductive group = 10.67 points (20.83 minus 10.16); inductive group = 9.70 points (20.39 minus 10.69); and, control group = 1.83 (10.01 minus 8.18).

Table 1 presents the ANCOVA data. Neither main effect was significant for either of the dependent variables when all the subjects were considered. The interaction of cognitive style and instructional sequence indicated support for the hypothesis but failed to reach significance for both dependent measures. A Scheffe multiple range test found the mean posttest score of the FI students using IND materials to be significantly higher than the means of the other three groups ($F(3,314) = 5.36$, $p < .001$). Figure 1 presents this data graphically. None of the other multiple comparisons showed a significant difference.

The second ANCOVA considered only those subjects who were greater than one standard deviation from the mean GEFT score. These cases were referred to as the extreme cases of FD and FI. This distinction was possible only because field-dependence-independence is a normally distributed variable. Neither the main effect of cognitive style nor instructional sequence were significant for either dependent variable. However, the interaction of cognitive style and

instructional sequence was significant. Table 1 presents these ANCOVA summary statistics and Figure 2 shows the treatment group mean values. A Scheffe multiple range test performed on the mean posttest scores showed the FI subjects who received the DED materials did significantly worse than the other three groups of students ($F(3,171) = 4.32$, $p < .001$), and that the FI subjects who received IND materials did significantly better than the other students ($F(3,171) = 6.12$, $p < .001$). When the dependent variable of gain score was used in the Scheffe analysis, the FI students who used IND materials reached a higher level of achievement than the other students ($F(3,171) = 3.66$, $p < .05$).

Discussion and Conclusions

The instructional materials were shown to be effective in their presentation of genetics and probability. Both the IND and DED groups increased their achievement on the average on the posttest 100% over their pretest score. The control group gained nearly two points with no instruction. Thus, two points out of the ten points gained by the treatment groups might have been due to something other than the treatment instructional materials.

A gain score was calculated and was used as a dependent variable in all of the final analyses. This calculation was made to remove the initial advantage that some students might have had due to the type of school attended or a greater amount of previous knowledge of genetics and probability. The gain score indicated the acquisition of new knowledge, which was considered important.

The interaction of cognitive style and instructional sequence in the ANCOVA which included all the subjects (Table 1 and Figure 1) was not significant. However, when only those subjects found in the tails of the field-dependence-independence continuum were considered, the interaction reached significance at the .001 level (Table 1 and Figure 2). This selection was made to magnify and clearly illustrate the difference in performance between the FI and FD

student groups. The nature of the treatment-aptitude interaction was such that the FI subjects experienced greater success with the IND materials and the FD subjects experienced greater success with the DED materials.

The results of this study dealing with the extremely FI and FD students are consistant with the original hypothesis and are supported by the findings reported in the literature. When the effect of general intelligence was removed by ANCOVA, neither the main effect of cognitive style nor instructional sequence had a significant effect upon the level of achievement of the students. However, cognitive style and instructional sequence interacted in such a way that the FI subjects experienced a higher level of achievement with IND materials and the FD subjects experienced a higher level of success with DED materials. The ANCOVA of all subjects support this finding but fail to reach significance.

Implications

The ability to solve problems with ease parallels Piaget's formal thinking and the degree of FI which a student demonstrates (Saarni, 1973). Many researchers maintain that high school students are concrete, or at best, transitional thinkers (Lawson et al., 1976; Piaget, 1972) and that they might find inductive or inquiry based materials difficult. It is possible that the frustration and failure attitude associated with an inquiry or inductive approach may do more motivational harm than good at this stage of logical maturity and that an alternative instructional strategy may be more appropriate. A recommendation of this study would be to individualize instruction in such a way that global (FD) students are matched with deductive materials and analytic (FI) students are matched with inductive materials. Individualizing for two broad groups of students is a reasonable task for the classroom teacher which may increase student success, hopefully resulting in more positive attitudes and self-concepts.

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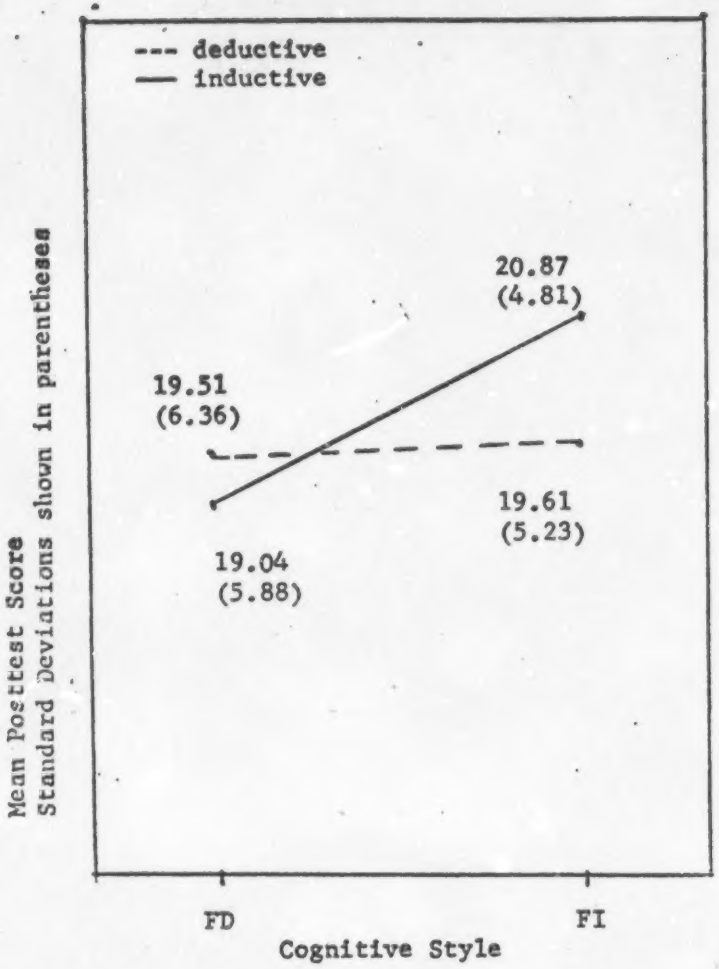
TABLE 1

Two-way ANCOVA of Cognitive Style and Instructional Sequence on Posttest Score and Gain Score[a]

Source	All Subjects			Extreme Cognitive Style		
	df	MS	F	df	MS	F
Cognitive Style	1	45.56 (27.76)	1.42 (.74)	1	12.20 (18.79)	.41 (.52)
Instructional Sequence	1	7.80 (41.97)	.24 (1.13)	1	2.93 (6.10)	.10 (.17)
Interaction	1	100.23 (128.71)	3.12+ (3.45)+	1	185.82 (268.97)	6.12** (7.40)**
Residual	314	32.10 (37.31)		171	29.90 (36.49)	

** $p < .01$ + $p < .10$

[a]Gain score data shown in parentheses.



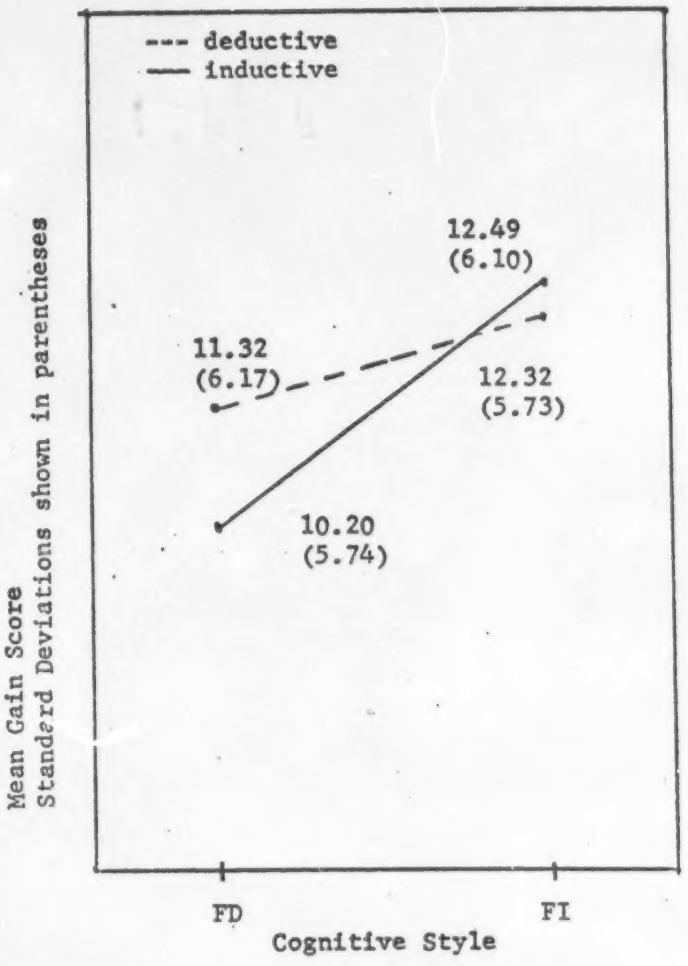
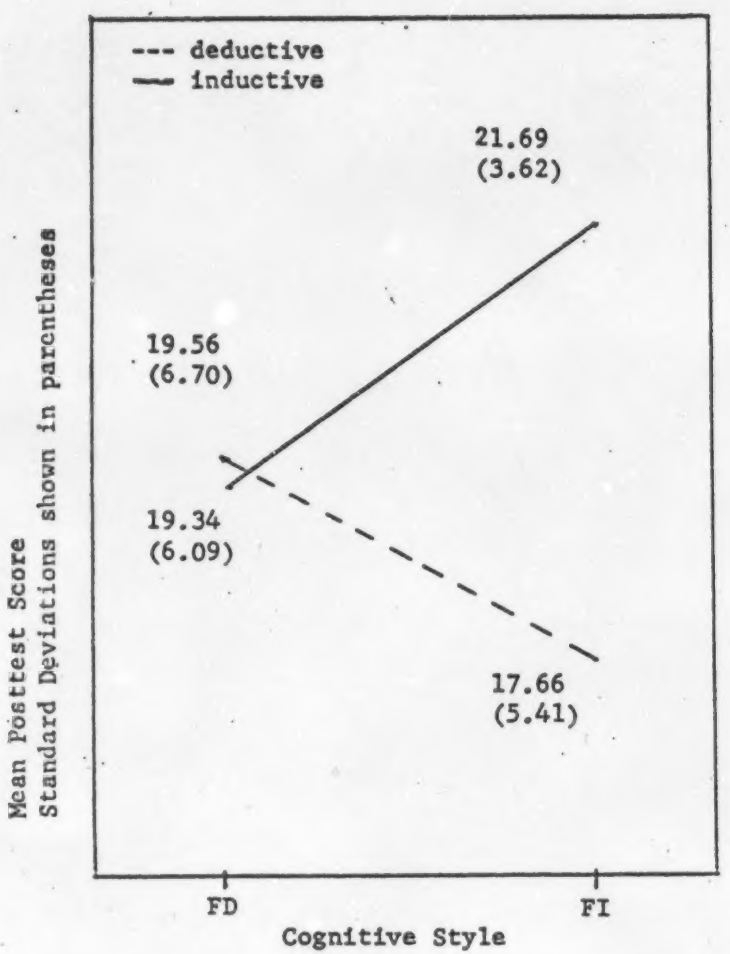


FIGURE 1

Interaction of Cognitive Style and Instructional Sequence

of all Students after ANCOVA



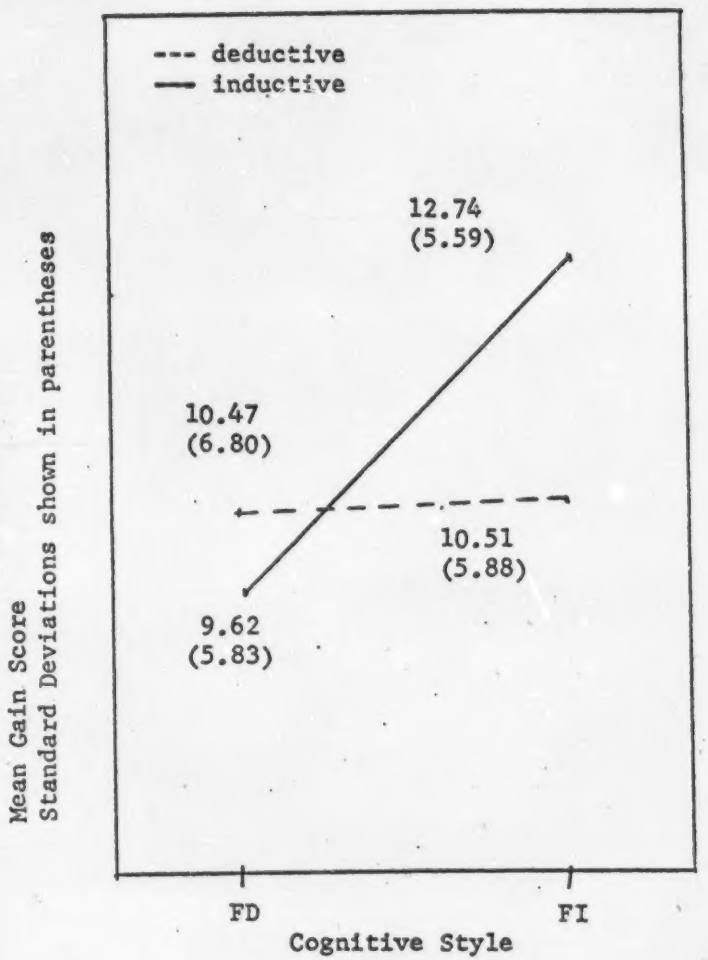


FIGURE 2

Interaction of Extreme Cognitive Style and Instructional Sequence after ANCOVA